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Using an Integrated Capability Maturity Model â – The FAA Experience

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Abstract. The Federal Aviation Administration (FAA) developed an integrated Capability Maturity Model (CMM), known as the FAA-iCMM®, that integrates the Systems Engineering CMM, the Software Acquisition CMM and the CMM for Software. The FAA-iCMM was released in 1997 and is the first major integrated CMM in existence. Since 1997, it has been successfully guiding the systematic improvement of FAA-wide processes used to manage, acquire, and engineer systems, products, and services.

This paper describes FAA's pioneering experience pursuing integrated process improvement using the FAA-iCMM. Lessons learned are presented regarding model representation, goal setting, the improvement infrastructure, training, transitioning, and appraisal. Plans to evolve the model and relationships with the government-industry-SEI CMM Integration (CMMI) effort are also discussed.

The paper will be of interest to any organization that seeks enterprise-wide process improvement and that might consider using an integrated capability maturity model to guide that effort.

INTRODUCTION

A current concern among the systems and software engineering communities is the relative isolation of these disciplines, and integrated process improvement guidance has been suggested as a means to remedy this situation (see e.g. Boehm 2000; Bate 1998). In 1997, the FAA developed the first integrated capability maturity model, the FAA Integrated Capability Maturity Model (FAA-iCMM) (Ibrahim et.al. 1997), to help solve this problem. This paper provides a brief overview of the FAA-iCMM and then describes its deployment, experiences in pursuing integrated process improvement, and planned next steps based on these experiences.

BACKGROUND

The Need for Integration. The FAA developed the FAA-iCMM to guide improvement of its engineering, management, and acquisition processes in an integrated, effective, and efficient way. In 1996, three single-discipline CMMs had been being used separately in different FAA directorates: the CMM for Software (SW-CMM v1.1) (Paulk et. al. 1993) the Systems Engineering CMM (SE-CMM v1.1) (Bate et. al. 1995), and the Software Acquisition CMM (SA-CMM v1.01) (Ferguson et. al. 1996) . While some improvements were being made, the single-discipline CMMs were being used in an uncoordinated way and without much success. These CMMs have different architectures, goals, terminology, and appraisal methods; they entail considerable overlap; and none alone covers all FAA system life cycle activities. Thus improvement efforts were suboptimal and the goal of FAA-wide, full life cycle, cross-discipline process improvement remained elusive. In addition, the FAA had moved to using integrated product teams as the implementation arm for its new Acquisition Management System and these teams needed processes that interrelated their disciplines.

The FAA-iCMM. The FAA-iCMM faithfully and robustly captures and integrates all principles, concepts, and practices of the SW-CMM, the SE-CMM, and the SA-CMM. It contains 23 process areas that integrate the 52 process areas and key process areas of its 3 source models. Each process area contains goals and base practices, integrated from the best practice guidance of the source models.

As in a continuous model, generic practices guide the improvement of the capability of the process areas. Additionally, the process areas are grouped or staged into maturity levels to provide guidance regarding what areas to focus on next. The FAA-iCMM representation is known as the continuous representation with recommended staging. It provides a path for improving both process capability and organizational maturity.

In order to measure progress, the FAA developed the FAA-iCMM Appraisal Method (FAM) (Ibrahim et. al. 1999) that integrates a variety of approaches for appraising vs. the integrated model. The model and its

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appraisal method offer guidance for integrated, systematic improvement of engineering, acquisition, and management processes.

The 23 process areas of the FAA-iCMM, with their maturity level stagings, are shown in Table 1. Table 2 lists the generic practices. Details of mappings of source process areas and practices to the FAA-iCMM are provided in (Ibrahim et.al. 1997) and additional architectural mappings are provided in (Ibrahim 1998).

Staging	FAA-iCMM Process Area
Maturity Level 2	Needs
	Requirements
	Outsourcing
	System Test and Evaluation
	Transition
	Project Management
	Contract Management
	Quality Assurance and Management
	Configuration Management
Maturity Level 3	Architecture
	Alternatives
	Software Development and Maintenance
	Integration
	Risk Management
	Coordination
	Peer Review
	Organization Process Definition
	Training
Maturity Level 4	Product Evolution
	Measurement
Maturity Level 5	Prevention
	Organization Process Improvement
	Innovation

Table 1: Process Areas and their Maturity Level Stagings

Capability Level	FAA-iCMM Generic Practice
Capability Level 1	Perform the process
Capability Level 2	Establish policy
	Allocate adequate resources
	Assign responsibility
	Ensure training
	Document the process
	Plan the process
	Use a repeatable process
	Manage configurations
	Assess process compliance
	Verify work products
	Measure process
	Review status
	Take corrective action
	Coordinate within the project
Capability Level 3	Standardize the process
	Use defined process
	Perform reviews with peers
	Coordinate with affected groups
Capability Level 4	Establish quality objectives for product and process
	Select processes for measurement
	Select measures for the process
	Determine quantitative process capability
	Use quantitative process capability
Capability Level 5	Perform continual process improvement on the organizational standard and tailored processes
	Implement improved processes

Table 2: Generic Practices and their Capability Levels

DEPLOYING THE MODEL

FAA's Integration Era (1997-2000). The FAA-iCMM rapidly became the single framework for CMM-based improvement in the FAA. In 1997, the Associate Administrator for Research and Acquisition (ARA) targeted selected major acquisition programs to achieve maturity level 2 on the FAA-iCMM by December 1999. Soon several additional programs and organizations across the FAA life cycle began applying the FAA-iCMM, including FAA's System Requirements Service organization. In 1999, ARA and the Associate Administrator for Air Traffic Services (ATS) committed to a common FAA-iCMM based process improvement goal to realize *high quality solutions to Agency and user needs, predictable cost and schedule, and increasing productivity*. FAA's operational support organization committed its engineering programs to FAA-iCMM based process improvement, and the office of independent test and evaluation adopted the FAA-iCMM.

Early Results. In 1999, the FAA Technical Center achieved its goal of capability level 2 in four FAA-iCMM process areas. Then in early 2000, an extensive full life cycle appraisal determined that several major FAA acquisition and engineering programs have

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achieved FAA-iCMM maturity level 2. In addition, capability level 2 in several process areas was uniformly achieved in programs appraised across the FAA life cycle. Early anecdotal data indicate that FAA-iCMM based improvement efforts have led to: better predictability, improved communication, improved teamwork, increased quality, greater consistency, cost savings, cost reductions, time savings, clarity of roles and responsibilities and processes, a more streamlined work effort, easier training of new hires, and more appreciation and attention to the roles of different disciplines and processes. First cost-benefit analyses have convinced the Agency that integrated process improvement provides value. More formalized quantitative measures are being established.

EXPERIENCES AND LESSONS LEARNED

Adopt an Integrated Model. From FAA's experience, the use of single discipline models in a multi-discipline organization leads to inefficiency and ineffectiveness in processes and in process improvement. Without an integrated model, cross-discipline improvement remains elusive, and efforts are suboptimal.

Set Joint Performance Goals. Working with an integrated capability maturity model offers powerful opportunities for enterprise-wide collaboration, and establishing high-level performance goals is the way to make that happen. At the FAA, early performance goals jump-started parts of the Agency on an aggressive path to maturity level 2. As experience was gained, joint performance goals were established across more of the agency reflecting increasing emphasis on integrated improvement across lines of business, functions and life cycle phases. Joint goals across directorates and lines of business are a critical success factor in transitioning to integrated process improvement and in synchronizing efforts of integrated product teams.

Align Process Improvement Goals with Business Objectives. Use the integrated model wisely. The FAA-iCMM's continuous representation with recommended staging enables goal setting aligned with the needs and objectives of different parts of the organization. It facilitates achieving goals that focus on improving (to any desired level) the capability of selected core critical process areas. For example, at the FAA, some executives adopted additional process improvement "stretch goals" in areas critical to their operations.

The model also facilitates establishment of the management and cultural foundations that come through achieving maturity levels. However, especially with an integrated model, not all process areas may be applicable to every part of the organization.

Regardless of the approach, goals should be expressed in terms of business needs. Keeping an eye on value-added diminishes the "check-the-box" mentality that might arise during process improvement efforts. To ensure that process improvement is directly tied to the business, align integrated process improvement with other initiatives, communicate relationships between process improvement and other goals, and provide guidance on priorities.

Think Enterprise. Integrated process improvement will surface many cross-organizational issues for resolution. It heightens cross-organizational understanding, appreciation, and problem solving; it requires cross-organizational cooperation. Implementing the FAA-iCMM brings systems engineers, software engineers, and acquisition managers together to clarify and interrelate what they do. Roles and responsibilities of different parts of the enterprise become clear; gaps become apparent.

Establish an Integrated Infrastructure. Integrated process improvement isn't easy and it requires an integrated infrastructure to make it happen. The FAA process improvement infrastructure includes: sponsors at several levels starting with the Chief Information Officer and Associate Administrators; process groups at several levels starting with the corporate integrated process group; corporate working groups including cross-organizational teams for FAA-iCMM evolution, metrics, training, communication, process asset library, appraisal, and others; plus process action teams.

At the FAA, these groups have evolved over time. It is even more important when pursuing integrated, cross-discipline, cross-line-of-business improvement to secure *top management* sponsorship and commitment An *enterprise-wide* process group is needed to lead, advocate and coordinate the effort. It should be staffed with executives and senior technical people who are widely respected, motivated, "turf-challenged," empowered, and persistent. The practitioners on the process action teams need to have adequate time allocated so they can improve *their own* processes.

Offer Training Continuously. At the FAA, a corporate training group manages FAA-iCMM related training. Training on the model, the appraisal method, how to do process improvement, etc. is provided by in-house staff. Domain or discipline-specific training (for example in requirements engineering, project management, configuration management, quality assurance) is typically outsourced. About 3000 people have received training related to the FAA-iCMM. In response to interests of other organizations, and in view of the fact that the FAA-iCMM is not FAA specific, external FAA-

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iCMM training has been offered

What's different regarding training when working with an integrated model? For course selection and evaluation, it is advisable to involve subject matter experts from across the organization, and to ensure materials are tailored to the integrated approach. For example, a potential course would not just focus on "software" configuration management, or "systems" configuration management, but should be about "configuration management". Also, there may be ongoing training initiatives in the various disciplines and it is important to integrate process training with other competency-building initiatives. (see e.g. Burke 2000).

Integrated process improvement spreads since several disciplines are involved, and it becomes institutionalized through widespread training and workshops.

Ensure Recognition that Legacy Investments are not Lost. Since several organizations in the FAA had been using the stand-alone CMMs, it was important to prepare for transitioning to the integrated model. Critical aids for this transition have been the extensive mapping tables included in the model. They facilitate transition from any source model to the FAA-iCMM because it is easy to identify where each practice and feature is placed in the integrated model. This reassures practitioners that the work they have done is not lost, but is part of the integrated effort. Also, specific guidance has been prepared (Ibrahim 1999) and workshops have been held to identify what's new, what's different, and what's the same between maturity level 2 on the FAA-iCMM and maturity level 2 on the SW-CMM.

Since the FAA-iCMM is described using a continuous representation with recommended staging, it was also very important to map the terminology, features, and principles from the staged and continuous source models to this new integrated representation. From FAA's experience, it was not difficult for those already familiar with either the staged or the continuous representation to understand the new architecture as long as mappings were explained.

Adopt the Continuous Representation with Recommended Staging. Although the debate continues regarding whether the staged or the continuous representation "is better" (SEPG 2000), and the CMMI effort has decided to issue separate integrated CMMs in both representations (CMMI 1999), FAA's experience has been that the features of both representations, together, are necessary and important. Moreover, neither the staged nor the continuous representation alone serves cross-organizational needs. By developing and implementing the FAA-iCMM using a continuous representation with recommending staging, FAA has found that guidance for enhancing both process capability and organizational maturity can be offered by the same model, using consistent terminology. Since unnecessary confusion, complexity, and divisiveness have resulted from perpetuating both representations, the distinct representations should be eliminated while retaining the important features of both in a single representation. Legacy investments based on models in one or the other representation are not lost, and process improvement practitioners are quick to understand and recognize CMM principles in a single format. From FAA's experience, one integrated architecture is both necessary and sufficient.

Recognize the "three for one" efficiencies and benefits. Improving an integrated process improves all 3 disciplines at once, as applicable, and attaining a maturity level on the FAA-iCMM is comparable to achieving equivalent levels on all 3 source models.

For example, the 9 process areas of the FAA-iCMM that are staged at maturity level 2 (see Table 1) integrate the practices and activities performed of 8 process areas of the SE-CMM, 9 key process areas of the SA-CMM, and 6 key process areas of the SW-CMM (plus selected activities of 2 additional SW-CMM key process areas). Achieving maturity level 2 on the FAA-iCMM is a major accomplishment since it means that those 9 process areas are each being performed at a planned and tracked level 2 capability (e.g. the level 1 and level 2 generic practices shown in Table 2 are being applied to each of those 9 process areas). This is equivalent to achieving maturity level 2 on the SW-CMM *plus* maturity level 2 on the SA-CMM *plus* capability level 2 on the 8 process areas of the SE-CMM that are mapped to the 9 FAA-iCMM maturity level 2 process areas.

Have a Variety of Appraisal Methods. The FAA-iCMM appraisal method actually comprises a set of 6 appraisal methods, 5 of which are structured as variations of the standard full FAM framework. Some of the variations have been adapted and integrated from various assessment and evaluation methods that were used with the source models; others are original to the FAA. Many FAA-iCMM appraisals have been conducted and most methods have been used, including the full internal, interview-based, questionnaire-based, document-intensive, and facilitated discussion appraisal methods. Only the full external method (intended for use in external evaluation) has not be applied.

Each method serves a different purpose and it has been very useful to have a variety of appraisal methods to meet needs for initial, quick-look, interim, and full formal appraisals. All methods are tailored to sponsor

needs, and accordingly appraisal scope has varied to include organizational appraisals or project appraisals, selected process areas or full maturity level appraisals, and appraisals up to different capability levels.

Enlist High-level Appraisal Sponsorship and Cross-organizational Appraisal Teams. With an integrated model it is especially important to seek high level appraisal sponsorship for full life cycle, cross-disciplinary coverage. In this way, potential gaps and interface problems possibly uncovered during an appraisal can be fully explored, integrated roles and responsibilities across the sponsor's organizations can be clarified during the appraisal, and interdisciplinary findings can be acted upon as endorsed by the sponsor.

Conducting an appraisal vs an integrated model is a major organizational learning tool for both appraisal participants and appraisers. Establishing cross-organizational, multi-disciplinary appraisal teams spreads the learning opportunity across the disciplines.

Generic Practices Make Sense. The common sense appeal of applying generic practices to any process at all is key to applying CMM-based process improvement across multiple disciplines. The generic practices make sense, and the same concepts are used in improving any process. As one FAA executive put it, "This is Management 101."

Once the generic practice concepts become institutionalized, it becomes quite natural to extend their application to other processes and disciplines. It fosters the desire among practitioners to expand the model to include other processes the organization performs. This has been an important factor leading to FAA's "Enterprise Era."

NEXT STEPS

FAA's Enterprise Era (2001-2005). Experiences so far have laid the foundation for evolving the FAA-iCMM and expanding its application across the FAA. The vision is that the FAA-iCMM becomes the reference model to guide FAA enterprise-wide improvement. Best practice guidance from other widely used and recognized models and standards adopted by government and industry are now being considered for integration into the FAA-iCMM.

The general strategy to achieve the vision is to evolve the FAA-iCMM through a series of phases in order to address broader agency needs, thus providing integrated CMM-based process improvement opportunities across the FAA enterprise. The strategy includes maintenance of current content, expansion in new areas, and piloting.

Maintenance includes updating the model to incorporate improvements based on use and to retain currency (including consideration of CMMI releases and other evolving standards). Expansion includes expanding the model in various business and engineering areas that are critical to the agency such as strategic planning, investment management, security, safety, as well as important technical processes that are regularly performed such as operations, deployment, and field level maintenance. The idea is to include both business and technical process enhancements in the FAA-iCMM. Together they provide a holistic approach towards integrating enterprise-level goal setting and business results processes together with the technical processes to accomplish those goals. This is a means to seek overall enterprise excellence. New disciplines or processes are piloted prior to formal inclusion in the model.

Relationships with CMMI. The development of the FAA-iCMM was completed prior to the launching of the government-industry-SEI CMM Integration (CMMI) project. The fact that the FAA-iCMM was successfully developed has provided proof of concept for the CMMI project that CMM integration is possible. Moreover, the fact that the FAA-iCMM has been successfully implemented over the past 3 years provides demonstration to the engineering and acquisition communities that integrated process improvement using an integrated CMM is possible. Since the FAA has been participating in the CMMI effort via steering group membership and product team contributions, and communicating status of its efforts in numerous public forums, one might take the view that the FAA has been pioneering CMM integration for both the CMMI development project and its potential users.

The FAA-iCMM v1.0 however covers different disciplines than the CMMI project since acquisition is one of the disciplines the FAA chose to integrate with systems engineering and software engineering. Furthermore, as discussed above, additional disciplines are now being considered for integration into next releases of the FAA-iCMM. However, upgrades to FAA-iCMM content will take advantage of any new best practice or validated content that results from the CMMI effort. Similarly, it is expected that the CMMI effort will consider FAA products as input to its efforts as it has in the past.

Continued cooperation between the FAA-iCMM effort and the CMMI effort is anticipated.

Using the Model Outside FAA. The FAA-iCMM is not specific to the FAA. It can benefit any organization where systems engineering, software engineering and acquisition are performed, integration of engineering processes is a goal, and integrated product teams carry

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out engineering, management and acquisition activities.

Some external organizations have been applying the FAA-iCMM as an available and validated solution to the integration problem. Public courses are offered by the FAA periodically, and external lead appraisers are typically included on FAA appraisal teams so that they can gain and bring back to their organizations experience with the FAA-iCMM and its application.

CONCLUSIONS

FAA replaced 3 separate CMMs with the FAA-iCMM, containing all features of its source CMMs. FAA is successfully applying the FAA-iCMM to achieve integrated process improvement. A key ingredient for success in enterprise-wide, integrated, cross-disciplinary process improvement is organizational adoption of an integrated CMM.

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BIOGRAPHY

Linda Ibrahim joined the FAA in 1996. She is the technical lead for FAA-wide process improvement. She formulated the concept and led the development and implementation of the FAA's integrated Capability Maturity Model and its appraisal method. Linda received the Meritorious Achievement Award of the US Secretary of Transportation for her innovative work in CMM integration.

Linda has been working in software engineering for over 30 years, as practitioner, educator, and researcher; in government, industry, academic, and applied research environments; in the US, Europe, and the Middle East. She is a member of the Steering Group for the CMM Integration (CMMI) project.

Linda holds a BA in Mathematics , MS in Information Science, and Ph.D. in Electrical Engineering. She is a member of INCOSE, ACM, and IEEE.

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